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Fluazifop Toxicity to Quackgrass (*Agropyron repens*) as Influenced by Some Application Factors and Site of Application[1]

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Abstract. **The phytotoxicity of the butyl ester of fluazifop to quackgrass was enhanced by the addition of a nonionic surfactant and an oil additive either alone or in mixture to the spray solution. The enhancement caused by the surfactant was consistently greater than that caused by the oil additive. A higher level of quackgrass control was achieved at the carrier volumes of 100, 200, or 400 L/ha, than at 800 L/ha. Quackgrass growth inhibition was greater following application of small herbicide droplets which averaged 0.25 μl compared to larger herbicide droplets at each herbicide application rate. When droplet concentration was varied and different doses of the herbicides applied to plants, no significant differences were noted at the highest dose. However, at intermediate dose treatments, the least concentrated droplets (2.5 μg/μl) were most phytotoxic. Herbicide droplets placed at basal areas of leaves were more phytotoxic than when placed at lamina apices and middle areas. This effect was most pronounced on adaxial rather than abaxial surfaces. In general, application of droplets to younger leaves resulted in greater phytotoxicity than treatment of older leaves. Nomenclature: Fluazifop, (±)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propionic acid; quackgrass, *Agropyron repens* (L.) Beauv. #[3] AGRRE.**

Additional index words. **Additives, agral, actipron, droplet studies, carrier volume,** *Agropyron repens*, **AGRRE.**

INTRODUCTION

Successful control of perennial, rhizomatous quackgrass requires an effective herbicide to be absorbed by the plant and translocated to the rhizomes to kill the rhizome buds. Fluazifop, a postemergence, selective, systemic herbicide, has been shown to be highly effective against quackgrass when applied at rates of 0.5 to 1.0 kg ai/ha to actively growing plants which have three to six fully developed leaves (7, 16, 25).

The use of surfactants as adjuvants to enhance herbicide effectiveness has been the subject of long and intensive investigation. It is generally believed that surfactants aid penetration of a herbicide, although how this happens is not clear (15). There is evidence that increased herbicide penetration into leaves aided by surfactants may be related to an increase in droplet:leaf surface interface area, although increase in interface area alone cannot account for the enhancement of phytotoxicity obtained with surfactants. There is abundant evidence that surfactants increase spray retention and subsequent penetration of leaves by herbicides (13, 14). Surfactants also affect droplet formation by hydraulic nozzles as well as droplet behavior after formation. Furmidge (12) has described reduced droplet size, reduced bouncing of droplets on impaction with a solid surface, and increased wetting ability as major effects of surface-active agents. Surfactants may also solubilize the waxy cuticle barrier of plants to some extent, thereby facilitating herbicide entry (5, 15).

The surfactant 'Agral 90' (nonyl phenol ethoxylate) has been found to enhance the activity of the commercial formulation of fluazifop and is recommended for use (25). Chandrasena and Sagar (7) in their earlier studies achieved a high degree of quackgrass control with fluazifop postemergence sprays incorporated with Agral 90 at 0.1% v/v.

Actipron (1), a self-emulsifying oil additive containing 97% mineral oil, has also been found to enhance the foliar activity of herbicides (B. Kowalczyk, I.C.I., U.K., personal communication). Porter and Harvey (26) reported enhanced control of *Panicum miliaceum* L. with fluazifop in the presence of a crop oil concentrate. Anderson (2) also found evidence of increased foliar activity of fluazifop in the presence of a crop oil concentrate. Phytotoxicity of fluazifop to forage sorghum [*Sorghum bicolor* (L.) Moench.] increased with the addition of a crop oil (AtPlus 411F)[4] to the herbicide formulation (4). Oils aid penetration by reducing the surface and interfacial tensions, thus greatly improving the spreading and wetting properties of the spray solutions, with the result of enhanced coverage and retention of herbicides on the target species. Oils may also improve foliar uptake by reducing evaporation losses of volatile herbicides and by being slightly phytotoxic to the leaf surface causing some degree of solubilization of the waxy barriers (14, 15). Oils appear to vary in their effectiveness in increasing the phytotoxicity of various herbicides (22, 23).

Nalewaja & Skrzypczak (24) compared absorption and translocation of fluazifop in oat *(Avena sativa* L. var. 'Lyon'), with a range of various seed and petroleum oil additives. They found that absorption of fluazifop after 48 h was less when applied with safflower *(Carthamus tinctorius* L.) oil, sunflower *[Helianthus annus* (L.)] oil, soybean *(Glycine max* L. Merr.) oil, linseed *(Linum usitatissimum* L.) oil, and palm

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[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

[4]AtPlus 411F, a mixture of nonphytotoxic paraffin base petroleum oil (83%), polyol fatty acid esters and polyethoxylated derivatives (15%), and components ineffective as adjuvant (2%). I.C.I., U.K.

(*Elais guineensis* Jacq.) oil, than with petroleum oil. They reasoned that fluazifop may have been more soluble or adsorbed in the seed oils than in petroleum oils, and that this may have caused a slower release of fluazifop from the seed oils. In addition they pointed out that seed oils may not have penetrated the oat cuticle as well as petroleum oils (24).

The phytotoxicity of a foliar-applied herbicide is also influenced by application factors such as the carrier volume (3), herbicide droplet size, and droplet concentration (10, 11, 13, 17, 18, 19). The site of deposition of spray droplets and the leaf and plant growth stage have also been shown to influence herbicide uptake, translocation, and subsequent efficacy (8, 27).

Crammer and Duke (9) reported that fluazifop was more toxic to quackgrass when applied in carrier volumes of 9 and 37 L/ha using controlled-droplet applications, than in 233 L/ha with conventional nozzle spraying. However, Slack and Witt (28) failed to establish a difference in annual grass weed control by fluazifop applied in carrier volumes of 43, 118, or 236 L/ha with CDA, hollow core, and flat-fan nozzles, respectively. Buhler and Burnside (4) examined the phytotoxicity of the herbicide to forage sorghum, when applied in carrier volumes of 24, 48, 96, 190, 380, or 570 L/ha, and found the activity to increase as the carrier volume decreased.

This paper reports the results of several studies undertaken to evaluate the influence of different rates of the surfactant (Agral 90) and oil additive (Actipron) alone or in mixture, the carrier volume, the droplet volume and composition, and the site of application on fluazifop toxicity to quackgrass.

MATERIALS AND METHODS

Quackgrass plants were raised from rhizomes of a clone maintained at the Penyffridd Field Station of the University College of North Wales, Bangor, as described previously (7). Subsequently, plants were grown in John Innes No. 1 compost until they were 10 to 11 weeks old. All investigations were done using plants that had five to seven fully developed leaves and rhizomes. Experiments were done in a heated glasshouse (18 to 25 C, 60 to 65% relative humidity) in a photoperiod of 16 h, achieved by supplementing natural daylight with 400-watt mercury lamps. An Oxford Precision Sprayer fitted with an Allman No. 0 nozzle operating at 300 kPa was used for spraying. Droplet applications were made with a 1-µl microsyringe. After herbicide spraying or droplet applications, plants were completely randomized on the glasshouse bench until harvest and watered daily to the pot directly to avoid wetting the foliage. In all experiments the herbicide effects were mainly assessed by measuring the reduction in shoot dry weight at 30 days and also by observing regrowth subsequent to this harvest. All experiments were repeated.

Effect of surfactant and oil additive alone or in mixture. Quackgrass plants were treated with fluazifop doses of 0, 0.25, or 0.5 kg ai/ha with the surfactant Agral 90 at 0, 0.1, or 0.2% v/v. The oil additive Actipron was also incorporated at rates of 0, 0.1, 0.5, 1, or 2% v/v. Different sets of plants (eight replicates per treatment) were sprayed with all possible combinations of herbicide doses and additive rates. The carrier volume used was 200 L/ha.

Effect of carrier volume and surfactant levels. Quackgrass plants were sprayed with fluazifop doses of 0, 0.25, or 1.0 kg ai/ha using carrier volumes of 100, 200, 400, or 800 L/ha of water. The surfactant Agral 90 was incorporated into the spray solution at 0.1 or 0.4% v/v. To achieve the necessary variation in application volume using the same spray nozzle, the number of passes of the sprayer over the plants was varied.

Effect of droplet volume and composition. A solution containing fluazifop at 10.0 µg/µl with Agral 90 surfactant at 0.1% v/v was applied to quackgrass plants in droplet volumes of 0.25, 0.5, or 1.0 µl. The number of droplets (Table 3) was varied to give total herbicide doses of 20, 40, or 80 µg/plant. Droplets were placed equidistance apart on the adaxial median region of the third youngest leaf between 3 and 18 cm from the ligule.

In a second experiment, three treatment solutions containing fluazifop concentrations of 25, 50, or 100 g/L (2.5, 5.0, or 10.0 µg/µl) and Agral 90 at 0.1% v/v were prepared. The appropriate number of droplets (Table 4), each of 1-µl volume, was applied on the quackgrass plants to deliver doses of 20, 40, 80, or 100 µg/plant. Up to 32 droplets were placed on the adaxial median region of the third youngest leaf, between 3 and 18 cm from the ligule. In one of the treatments (droplet concentration 2.5 µg/µl) the remaining 32 droplets were applied to the fourth youngest leaf. In both experiments there were six replicate plants per treatment.

Effect of site of herbicide application. Fluazifop droplets (10 µg/µl) of 1-µl volume were placed at one of three positions on the third youngest leaf of the quackgrass plants: lamina base (between 0 and 5 cm from ligule); lamina middle (between 5 and 12 cm from ligule); and lamina apex (between 12 and 20 cm from ligule). Applications were made on separate plants to the adaxial or abaxial leaf surface. Either five or ten such droplets were applied per plant to deliver doses of 50 or 100 µg/plant, respectively.

In another experiment, herbicide droplets (10 µg/ µl) of 1-µl volume were applied on the youngest leaf (L1, not fully developed)[5], second, third, fourth, or fifth youngest leaves (L2, L3, L4, or L5, respectively, from the top)[5] of quackgrass plants. In each case five or ten droplets were applied on the adaxial median region of the leaves between 3 and 18 cm from ligule to deliver doses of 50 or 100 µg/plant. Both experiments had treatment solutions containing 0.1% v/v of Agral and six replicate plants for each treatment.

All results were subjected to conventional analyses of variance to determine significant effects. In all cases raw dry weight data were analyzed, and later the results expressed as percent reduction from untreated controls. Significant means were separated at the 5% level of significance by Fisher's Protected Least Significance Difference (LSD) Test. The data are first presented for significant main effects, followed by presentation and interpretation of significant interactions.

[5]Abbreviations: L1, L2, L3, L4, L5; youngest (not fully developed), second, third, fourth, and fifth youngest leaf, respectively, from the top.

Table 1. Quackgrass shoot dry weight reduction achieved by fluazifop with and without surfactant and oil additive[a].

Herbicide rate + surfactant concentration	Reduction in weight as affected by oil additive concentration (% v/v)					
	0	0.1	0.5	1.0	2.0	Mean
(kg/ha + % v/v)	(%)					
0 + 0	0	4.8	5.5	7.9	13.4	6.3 c
0 + 0.1	11.8	8.7	11.0	3.2	15.8	10.9 b
0 + 0.2	8.7	7.9	18.1	18.1	21.3	14.8 a
Mean	6.8 d	7.1 d	11.5 b	9.8 c	16.8 a	
LSD (0.05)[b]= 1.4						
0.25 + 0	41.7	47.3	56.7	52.8	52.0	50.1 b
0.25 + 0.1	66.2	70.1	79.5	82.7	83.5	76.4 a
0.25 + 0.2	71.7	74.8	77.2	79.5	81.9	77.0 a
Mean	59.9 d	64.1 c	71.1 b	71.7 ab	72.5 a	
LSD (0.05)[b] = 2.1						
0.5 + 0	54.3	78.8	83.4	82.7	83.5	76.5 b
0.5 + 0.1	80.3	82.7	85.0	85.8	87.4	84.2 a
0.5 + 0.2	82.7	84.3	83.6	88.2	86.6	85.1 a
Mean	72.4 d	81.9 c	84.0 b	85.6 ab	85.8 a	
LSD (0.05)[b] = 2.5						

[a]Mean values of a row or column, at each herbicide rate, that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.

[b]LSD (P = 0.05) for comparison of surfactant and oil additive effects within a herbicide rate.

RESULTS AND DISCUSSION

Effect of surfactant and oil additive alone or in mixture. The lower herbicide rate (0.25 kg/ha) caused 42% reduction of quackgrass shoot growth without any extra additive (Table 1). The same rate, without the oil additive but with surfactant, produced 66 to 72% reduction of quackgrass shoot growth. Without the surfactant, the range of oil additive rates caused 47 to 57% reduction of quackgrass. Addition of the two additives in mixture, however, resulted in significantly greater quackgrass control ranging from 70 to 83.5% reduction in shoot growth of the weed.

This effect was somewhat less at the higher herbicide rate of 0.5 kg/ha which reduced quackgrass growth by 54% without any additive. In the absence of the oil additive the surfactant alone caused a significant enhancement of the herbicide effects which resulted in 80 to 83% reduction in quackgrass growth. Without the surfactant the oil additive alone enhanced fluazifop activity to cause 79 to 83.5% reduction of the weed growth. At this herbicide rate, the mixtures of additives produced further significant improvement of activity resulting in 83 to 87% reduction of quackgrass growth.

It was apparent from this study that both additives were capable of causing significant improvement of the foliar activity of fluazifop against quackgrass. Also, the enhancement of herbicide activity, particularly at the lower rate, was greater with the surfactant Agral than with the oil additive Actipron. Furthermore, at both rates of the herbicide, the two additives in mixture caused greater suppression of quackgrass than did either additive alone. Without the herbicide, the oil itself and its mixture with Agral caused inhibition of the growth of quackgrass by 4 to 13% and 3 to 21%, respectively (Table 1). This indicated some degree of phytotoxicity of the additives to quackgrass.

The evidence obtained here strongly suggests that the mineral oil Actipron at rates of 0.1 to 2% v/v and surfactant Agral at rates of 0.1 to 0.2% v/v may be used either alone or in mixtures as adjuvants to enhance the activity of fluazifop. The additives probably improve the retention of the herbicide spray by the leaves and increase the droplet:leaf surface interface area, thereby allowing more uptake. The additives may also act as carriers which facilitate movement through the lipophilic pathway. These results (Table 1) are in general agreement with the data of others who have documented enhanced fluazifop phytotoxicity in the presence of oils and surfactants (2, 4, 24).

Effect of carrier volume and surfactant levels. In this experiment, at 800 L/ha nearly 100% wetting of quackgrass foliage occurred and much of the spray ran off the wet leaves. In sharp contrast, the 100 L/ha carrier volume consistently did not wet more than 30% of the target foliage (visual estimate). The two intermediate volumes caused wetting of foliage without any obvious runoff. Foliage injury scores at 14 days (data not presented) indicated that phytotoxicity was least at the highest volume.

In general, a higher level of quackgrass control was achieved with the higher fluazifop rate and at carrier volumes of 100, 200, and 400 L/ha, than at 800 L/ha (Table 2). Results indicated that at 800 L/ha, the phytotoxicity of the 1.0 kg/ha rate was reduced to a level comparable to that of the 0.25 kg/ha rate applied in 100 L/ha.

The amount of spray retained by a plant is influenced to a large extent by the carrier volume used to make up the spray solutions. The carrier volume also affects the degree to which the spray is distributed on the target foliage and the

Table 2. Quackgrass shoot dry weight reduction achieved by fluazifop applied with a range of carrier volumes and two levels of surfactant[a].

Fluazifop rate	Surfactant concentration	Reduction in weight as affected by carrier volume (L/ha)				
		100	200	400	800	Mean
(kg/ha)	(% v/v)	(%)				
0	. . .	0	0	0	0	
0.25	0.1	66.3	67.3	56.7	61.1	63.0 b
	0.4	64.8	63.0	60.8	48.5	59.0 b
1.0	0.1	80.6	76.8	78.3	65.1	75.0 a
	0.4	80.0	76.8	73.4	60.8	73.0 a
Mean		73.0 a	71.0 a	67.0 ab	58.0 b	
LSD (0.05)[b] = 10.5						

[a]Mean values of a row or column that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.
[b]LSD (P = 0.05) for comparison of carrier volume by dose means.

concentration of herbicide droplets. As shown by Blackman et al. (3) in their early work, and later confirmed by Caseley et al. (6) and Sandberg et al. (27), high carrier volumes are not very appropriate for use with well-translocated herbicides, especially in the control of easy-to-wet susceptible species. Higher carrier rates may cause runoff, and it is conceivable that biologically active material may be lost this way. Results of our study may also be explained the same way. Addition of a surface-active agent also may have contributed to reduced retention at the high carrier volume.

Herbicide concentration in the spray droplets also affects the rate of entry into leaves and hence the overall phytotoxicity (17, 18, 19). Higher concentration of herbicide in the spray droplets at lower carrier volume may increase phytotoxicity, as pointed out by Buhler and Burnside (4). These workers suggested that the higher concentration gradient resulting between more concentrated droplets and the leaf cells could lead to higher rates of herbicide diffusion into leaves.

Buhler and Burnside (4) examined the effect of carrier volume on the performance of three postemergence herbicides, including fluazifop, and reported an increase in phytotoxicity as the carrier volume decreased from 570 to 24 L/ha. In their study, increasing the herbicide dose from 0.01 to 0.1 or 0.2 kg/ha improved the control at low volumes, but when applied with 380 or 570 L/ha of carrier, these doses were less effective than at low volumes. They explained the improved performance on the basis of higher spray retention, higher droplet concentration, and smaller droplet size, which resulted from the use of smaller orifice nozzles to deliver low volumes. Our results clearly indicate that for quackgrass control with fluazifop, carrier volumes of 100 to 400 L/ha can be used successfully. The use of lower carrier volumes could reduce the time, equipment, cost, and fuel requirements of the herbicide application.

Effect of droplet volume and composition. The growth of quackgrass was increasingly reduced as the dose per plant increased (Table 3). At each dose, greatest inhibition of quackgrass growth was obtained with the smallest droplets. The effect was clearest at the highest dose (80 μg/μl) where 0.25-μl droplets caused a growth reduction of 67% compared to the two higher droplet volumes, both of which reduced the shoot growth of quackgrass by 46%. Slight scorching was also evident on the leaves, which received 1.0-μl droplets.

Table 3. Quackgrass shoot dry weight reduction achieved by fluazifop droplets containing 10 μg/μl, applied in three droplet sizes (volumes)[a].

Droplet volume	Reduction in weight as affected by dose (μg/plant)			
	20	40	80	Mean
(μl)	(%)			
0.25	11.4 (8)[b]	44.6 (16)	67.0 (32)	41.0 a
0.5	6.8 (4)	31.5 (8)	45.6 (16)	28.0 b
1.0	3.3 (2)	22.8 (4)	45.6 (8)	23.9 b
Mean	7.1 c	33.0 b	52.8 a	
LSD (0.05)[c] = 14.5				

[a]Mean values of a row or column that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.
[b]Number of droplets applied per plant to deliver the respective doses are given within parentheses.
[c]LSD (P = 0.05) for comparison of droplet volume by dose means.

Table 4. Quackgrass shoot dry weight reduction achieved by fluazifop droplets of varying concentrations. Droplet volume was 1 µl[a].

Droplet concentration	Reduction in weight as affected by dose (µg/µl)				
	20	40	80	160	Mean
(µg/µl)	(%)				
10.0	+10.9 (2)[b]	24.0 (4)	51.0 (8)	76.6 (16)	32.2 b
5.0	+ 7.7 (4)	17.4 (8)	49.6 (16)	82.9 (32)	35.6 b
2.5	+ 0.6 (8)	40.7 (16)	61.9 (32)	82.9 (64)	46.3 a
Mean	+ 6.4 d	27.4 c	54.2 b	80.9 a	
LSD (0.05)[c] = 15.6					

[a]Mean values of a row or column that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.

[b]Numbers of droplets applied per plant to deliver the respective doses are given within parentheses.

[c]LSD (P = 0.05) for comparison of droplet concentration by dose means.

The lowest dose applied (20 µg/µl) caused an increase in the number of tillers at the base of the plant, all of which were severely malformed.

In the experiment that studied the effect of droplet composition, at each droplet concentration there was increasing reduction in shoot growth as the dose increased. Differences in shoot growth suppression achieved by variable droplet concentration were not significant at the higher dose treatments (Table 4). However, the results indicated that the activity of the lowest droplet concentration (2.5 µg/ µl) was highest, since at 40 µg per plant this treatment did produce a significant effect. In this experiment the lowest dose (20 µg/ plant) did not reduce growth but produced an increase in tiller numbers and shoot dry weight. As in the previous experiment the tillers were severely malformed and exhibited pronounced chlorosis.

The experiments clearly showed that both droplet size and concentration influenced the activity of fluazifop. Greatest activity was achieved by the smallest droplets (0.25 µl), which averaged ca. 0.4 mm in diameter. It has been reported that when 2,4-D[(2,4-dichlorophenoxy)acetic acid] amine was applied to sunflower in droplet volumes of 0.1, 0.2, and 0.4 mm, the smallest droplets were herbicidally most effective (18). McKinlay et al. (17) found paraquat droplets of 0.1 mm to be more phytotoxic than 0.35-mm droplets at the same dosage. Difenzoquat (1,2-dimethyl-3,5-diphenyl-1*H*-pyrazolium) toxicity to wild oat [*Avena fatua* L.] was found to be greater when it was applied in 0.2-mm droplets than in 0.4-mm droplets (19). Buhler and Burnside (4), in their studies of uptake and translocation of fluazifop and two other postemergence herbicides by forage sorghum, reported that smaller, more concentrated droplets were more phytotoxic than larger, more dilute droplets. With all three herbicides, they found toxicity to be greater when the herbicide was applied as droplets of 1, 2, 4, and 8 µl than when droplet volume was increased to 24 µl. The commonest explanation given for these observations was that greater uptake generally occurred from smaller than larger droplets. In the present experiment it was possible that uptake was greater from a larger number of smaller droplets, compared to the reverse situation.

In these studies droplet concentration also affected the performance of fluazifop but to a lesser extent than droplet

Table 5. Quackgrass shoot dry weight reduction achieved by droplets of fluazifop placed on different positions of adaxial and abaxial surfaces of the third youngest leaf. Droplet concentration was 10 µg/ µl. Droplet volume at each position was 1.0 µl[a].

Leaf surface	Dose/plant	Reduction in weight as affected by position on leaf (distance from ligule)			
		Lamina base (0–5 cm)	Lamina middle (5–12 cm)	Lamina apex (12–20 cm)	Mean
	(µg)	(%)			
Adaxial	50	33.4	24.4	13.5	36.9 b
	100	57.0	57.6	39.8	
Abaxial	50	33.1	35.5	19.7	43.9 a
	100	61.2	62.7	50.8	
Mean	46.2 a	44.9 a	31.0 b		
LSD (0.05)[b] = 12.5					

[a]Mean values of a row or column that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.

[b]LSD (P = 0.05) for comparison of leaf surface, position on leaf by dose means.

Table 6. Quackgrass shoot dry weight reduction achieved by droplets of fluazifop placed on different leaves. Droplet concentration:10 µg/µl. Droplet volume:1.0 µl[a].

Dose/plant	Reduction in weight as affected by leaf treated[b]					
	L1	L2	L3	L4	L5	Mean
(µg)	(%)					
50	38.6	35.6	36.8	35.4	32.0	36.1 b
100	71.6	64.2	66.9	62.0	53.7	62.1 a
Mean	51.2 a	50.0 a	51.9 a	48.7 ab	43.8 b	
LSD (0.05)[c] = 6.6						

[a]Mean values of a row or column that are followed by the same letter are not significantly different (P = 0.05) according to Fisher's LSD Test.

[b]L1 = youngest leaf; L2 = second youngest leaf .....; L5 = fifth youngest leaf.

[c]LSD (P = 0.05) for comparison of treated leaf by dose means.

size. As pointed out by Ennis and Williamson (10), it is possible that more concentrated droplets cause killing of cells below the location on which they have landed; hence such droplets can become physiologically isolated, thus reducing absorption. Droplet concentrations in excess of 20 µg/µl were found to cause severe scorching of the droplet location in some of our own preliminary studies (data not presented). Merritt (19) also reported a loss of overall activity of difenzoquat on wild oat as the droplet concentration was increased from 25 to 200 µg/µl. However, droplet concentration did not markedly affect the performance of MCPA [(4-chloro-2-methylphenoxy)acetic acid] and paraquat (1,1′-dimethyl-4,4′-bipyridinium ion), while the activity of glyphosate [*N*-(phosphonomethyl)glycine] was increased as the droplet concentration increased (20). In our studies the greater effectiveness of the low droplet concentration may be a reflection of the greater number of droplets applied to deliver a given dose. This could mean that even though systemic herbicides are generally less dependent on coverage, in the case of fluazifop control of quackgrass, the herbicide activity could be greater if uptake occurred from a larger number of droplets.

Effect of site of herbicide application. At both doses, fluazifop was more effective when applied to the lamina base or lamina middle compared with applications to the lamina apex (Table 5). This effect was most pronounced on the adaxial treatments than on abaxial surfaces. Coupland et al. (8) reported enhanced glyphosate activity when it was applied to basal regions of leaves of wild oat and quackgrass, and they suggested that this could be due to the microclimate around the 'basal' areas being more humid, thus prolonging the time of uptake from droplets. The type and amount of epicuticular waxes in this basal region might also have been an important factor determining the effect of position (8). Similar explanations may hold true for fluazifop effects on quackgrass. Although some of the differences between individual treatments were not significant, the placement of droplets on abaxial surfaces caused greater phytotoxicity compared to treatments of adaxial surfaces.

Significant effects were produced by the treatment of leaves of different ages and by the herbicide dose (Table 6). With the lower dose, the growth reduction was similar from treatments to all leaves, except with the oldest (L5), the treatment of which resulted in a reduced effect. With the higher dose, greater inhibition was achieved by treating the younger leaves (L1, L2, L3) compared to applications to L5. It is generally thought that in the case of systemic foliage-applied herbicides, the effect of leaf age can be correlated with the ability of the leaf to export materials into the translocation stream (21). The present study indicated that application of fluazifop to all leaves except the oldest was equally effective in inhibiting the growth of quackgrass. Leaf L5, being the oldest down the culm, may have started to senesce and hence may not have been efficient in its uptake or export. Buhler and Burnside (4), in their study of fluazifop, haloxyfop {2-[4-[(3-chloro-5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid}, and sethoxydim {2-[1-(ethoxyimino)butyl] - 5 - [2 - (ethylthio)propyl]- 3 -hydroxy-2-cyclohexen-1-one} uptake by forage sorghum, also found that the site of deposition was not of great significance, provided the herbicides came into contact with metabolically active leaf tissue. Our results agree with this conclusion.

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